

## Sulphur, Zinc and Boron nutrition to improve production efficiency and profitability of Indian mustard in Bundelkhand region

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### Abstract

A field experiment was carried out to determine the impact of sulphur (S), zinc (Zn) and boron (B) on growth, productivity and profitability of Indian mustard during 2019-20 at Rani Lakshmi Bai Central Agricultural University, Jhansi, Uttar Pradesh. The experiment laid out in split plot design with three levels of S as in main plot viz., 0, 20 and 40 kg S ha<sup>-1</sup> and six levels of Zn and B viz., control, 2.5 kg Zn, 5.0 kg Zn, 0.5 kg B, 1.0 kg B and 2.5 kg Zn + 0.5 kg B ha<sup>-1</sup> as in sub-plot and replicated thrice. Experimental data revealed that application of 40 kg S ha<sup>-1</sup> proved to be more efficient in term of growth, yield and economically over 0 kg S ha<sup>-1</sup> as evident by higher CGR during 31-60 DAS (17.6 g m<sup>-2</sup> day<sup>-1</sup>), seed yield (1.84 t ha<sup>-1</sup>), net returns (58108 Rs. ha<sup>-1</sup>), production efficiency (13.49 kg ha<sup>-1</sup> day<sup>-1</sup>) and profitability (434 Rs. ha<sup>-1</sup> day<sup>-1</sup>). Among Zn and B levels, application of 5 kg Zn ha<sup>-1</sup> exhibited highest CGR (17.4 g m<sup>-2</sup> day<sup>-1</sup>) and RGR (95.1 mg g<sup>-1</sup> day<sup>-1</sup>) during 31-60 DAS and maximum seed yield (1.79 t ha<sup>-1</sup>), net returns (56709 Rs ha<sup>-1</sup>), production efficiency (13.18 kg ha<sup>-1</sup> day<sup>-1</sup>) and profitability (423.2 Rs. ha<sup>-1</sup> day<sup>-1</sup>) were recorded with combined application of 2.5 kg Zn + 0.5 kg B ha<sup>-1</sup>.

**Keywords:** Indian mustard, production efficiency, profitability, sulphur, zinc

### Introduction

Oilseeds play an instrumental role in agricultural economies worldwide and contribute significantly to agro-industries and global trade. India ranks as the fourth largest oilseed producer globally, following China, USA, and Brazil. It accounts for 10% of global oilseed production, 6% of world vegetable oil production, and approximately 7% of protein meal production (Nayak *et al.*, 2022). Rapeseed-mustard is second most important edible oilseed crop in our country after soybean, among all the nine oilseed crops. India occupied 8.06 mha area under rapeseed-mustard and 11.75 mt of production with average productivity of 1458 kg ha<sup>-1</sup>, which is about three-fourth of the world's average productivity (1960 kg ha<sup>-1</sup>) (DA&FW, 2023). Uttar Pradesh secured third position in the country in respect of both acreage (0.76 mha) and production (1.03 mt) of rapeseed-mustard after Rajasthan and Haryana (DA&FW, 2023). The Bundelkhand region produced 1.85 lakh tonnes of rapeseed-mustard under an area of 2.11 lakh ha with an average productivity of 871 kg ha<sup>-1</sup> (DES, 2024). Poor soil fertility, negligence about secondary and micronutrient in crop production, biotic and abiotic stresses are the major factors responsible for low productivity of rapeseed-mustard.

Therefore, application of secondary and micronutrient in rapeseed-mustard crop production is the need of the

hour. Sulphur is the fourth most important nutrient in crop production to increase the quality and productivity of mustard next to N, P and K (Atkari *et al.*, 2022). Oilseeds require more amount of S (12 kg) to produce one tonne of economic yield as compared to pulses (8 kg) and cereals (3-4 kg) (Kumar and Chauhan, 2005). It has been reported that S application enhanced mustard yield both under irrigated and rainfed conditions by 12-48% and 17-124%, respectively (Shekhawat *et al.*, 2012). Beside S, mustard crop is responsive to micronutrients application especially zinc and boron in moderate to low fertile soils (Kumar, 2012). It has been reported that Zn plays an important role in enhancing yield of maize, wheat (Joshi *et al.*, 2020), pearl millet, and fenugreek (Kumawat *et al.*, 2022) by activating several enzymes, such as carbonic anhydrase, dehydrogenase, aldolase, alkaline phosphatase, ribulose biphosphate carboxylase, RNA polymerase and phospholipase which regulate various metabolic processes in the various crop plants (Kumawat *et al.*, 2022). Moreover, B is the second most essential micronutrient in mustard after zinc (Ahamad *et al.*, 2012). It plays an important role in the cell division, differentiation and essential for reproductive growth of plant, pollen viability, seed and fruit development in crop plant (Havlin *et al.*, 2013). Mustard crop responds well to B application with an average of 21-31% enhancement in productivity (Shekhawat *et al.*, 2012). In this regard, the current study was hypothesized that S,

Zn, and B application will have instrumental role in enhancing the yield quality of Indian mustard. The objective of the study was to evaluate the effect of S, Zn and B in improving the growth, productivity and profitability of Indian mustard.

### Materials and Methods

A field experiment was conducted under irrigated condition during *Rabi* season of 2019-2020 at Rani Lakshmi Bai Central Agricultural University, Jhansi, Uttar Pradesh. The experimental site located in the Central Plateau and Hills Region (Agro Climatic Zone-VIII) at 25°31'07.1" N latitudes, 78°33'47.4" E Longitude and at an altitude of 284 m above MSL. The climate of Bundelkhand and region is sub-tropical and subjected to intense hot summer and cold winter. Annual rainfall of Bundelkhand and region varies from 850 to 1000 mm and it is characterized as sub-humid region. The total rainfall during the experimental period (November, 2019–March, 2020) was 41.6 mm, of which 8.2, 24.6 and 8.8 mm was received during December, January and March, respectively. The average maximum and minimum temperature were 24.5°C and 10.0°C, respectively. However, total cumulative pan evaporation was 60.8 mm during entire cropping period. The soil of experimental field was loam in texture with 6.8 pH, 0.20 dS m<sup>-1</sup> EC at 25°C, 0.51% in organic carbon, 260.5 kg ha<sup>-1</sup> of available N, 18.1 kg ha<sup>-1</sup> available P<sub>2</sub>O<sub>5</sub>, 241.8 kg ha<sup>-1</sup> available K<sub>2</sub>O, 21.5 kg ha<sup>-1</sup> available S, 0.57 mg ha<sup>-1</sup> available Zn and 1.28 mg ha<sup>-1</sup> available B as an initially fertility status.

The experiment was laid out in split plot design comprising three sulphur levels (0, 20 and 40 kg S ha<sup>-1</sup>) to the main-plots, and six Zn and B levels (control, 2.5 kg Zn ha<sup>-1</sup>, 5.0 kg Zn ha<sup>-1</sup>, 0.5 kg B ha<sup>-1</sup>, 1.0 kg B ha<sup>-1</sup>, 2.5 kg Zn ha<sup>-1</sup> + 0.5 kg B ha<sup>-1</sup>) to sub-plots with three replications. The mustard crop was uniformly applied with 80 kg N, 40 kg P<sub>2</sub>O<sub>5</sub> and 40 kg K<sub>2</sub>O ha<sup>-1</sup> as recommended dose of fertilizer. The requisite quantity of each S, Zn, and B treatments were applied plot-wise as per treatment through basal application. The application of S was done by using bentonite-S, which contained 90% of S as SO<sub>4</sub><sup>2-</sup>, while the application of Zn was done by using Zinc Oxide (78% Zn) and the application of B by using Borax (11% B). Mustard cultivar 'DRMRIJ-31 (Giriraj)' was sown in rows at 45 cm apart with 4 kg seed ha<sup>-1</sup>. Pre-sowing irrigation was applied one week before sowing and later two irrigations were applied at 29 and 67 DAS, respectively. The mustard crop took 134 days to attain harvest maturity.

Crop growth rate (CGR) indicates increase in dry weight (w) of a plant per unit time (t) per unit land area (m<sup>2</sup>). It is computed by the below mentioned formula at 30, 60 and 90 DAS and expressed as g m<sup>-2</sup> day<sup>-1</sup>.

$$CGR = (W_2 - W_1) / (t_2 - t_1) \times 1 / \text{Land area}$$

Where, W<sub>2</sub> and W<sub>1</sub> are dry weight (g) of plant in m<sup>2</sup> land area at time t<sub>2</sub> and t<sub>1</sub>, respectively.

Relative growth rate (RGR) is represented as the amount of dry matter produced per unit existing dry matter per unit time. It is computed by given formula at 30, 60 and 90 DAS and expressed as g g<sup>-1</sup> day<sup>-1</sup>.

$$RGR = (\log_e W_2 - \log_e W_1) / (t_2 - t_1)$$

Where, W<sub>2</sub> and W<sub>1</sub> are dry weight (g) per plant at time t<sub>2</sub> and t<sub>1</sub>, respectively.

Production efficiency (PE) was worked out as incremental seed yield on a daily basis (Tomar and Tiwari, 1990) by the formula:

$$PE = (SY_e - \sigma) / \Delta n$$

Where, PE is the production efficiency in kg ha<sup>-1</sup> day<sup>-1</sup>, SY<sub>e</sub> is the economic yield in kg ha<sup>-1</sup>, σ=estimate of standard error and Δn is the duration of the crop (134 days).

The net returns were calculated by deducting the total expenditure incurred on field preparation, seeds, fertilizers, irrigation, agrochemicals for insect-pests and diseases, harvesting, and threshing from the gross returns. The profitability was calculated to determine per day return (Sheoran *et al.*, 2018). Profitability was calculated as:

$$P = NR/D$$

Where, P is the profitability in Rs ha<sup>-1</sup> day<sup>-1</sup>, NR is the net returns, and D is the duration of the crop. Economics of the treatments were computed taking into account the prevailing market prices of inputs and crop outputs. Data were analyzed statistically in SAS @ version 9.3 for analysis of variance (ANOVA). Treatments were compared by computing the 'F test'. The significant differences between treatments were compared by critical difference at 5% level of probability (Gomez and Gomez, 1984).

### Results and Discussion

Perusal of data (Table 1) indicated that varying levels S application influenced crop growth rate (CGR) during 31–60 DAS significantly. Crop growth rate (31–60 DAS) was recorded significantly higher with the application of 40 kg S ha<sup>-1</sup> as compared to control (0 kg S ha<sup>-1</sup>), while statistically comparable with application of 20 kg S ha<sup>-1</sup>. This is due to the role of sulphur in photosynthesis, carbohydrate formation and better development of internal tissue, which rapidly increased dry matter accumulation (Thompson, 1967). The effect different levels of Zn and B application were observed significant during 31 to 60 DAS (Table 1). The

Table 1: Effect of sulphur, zinc and boron on CGR, RGR, seed yield, net returns, production efficiency and profitability of Indian mustard

Treatments	CGR (g m <sup>2</sup> day <sup>-1</sup> )		RGR (g g <sup>-1</sup> day <sup>-1</sup> )		Seed Yield (t ha <sup>-1</sup> )	Net Returns (Rs. ha <sup>-1</sup> )	Production Efficiency (kg ha <sup>-1</sup> day <sup>-1</sup> )	Profitability (Rs. ha <sup>-1</sup> day <sup>-1</sup> )
	31-60 DAS	61-90 DAS	31-60 DAS	61-90 DAS				
S levels (kg ha <sup>-1</sup> )								
S0	15.6	16.2	91.7	22.7	1.52	44970	11.05	335.6
S20	16.9	16.9	94.3	22.1	1.72	53516	12.62	399.4
S40	17.6	17.5	95.4	22.0	1.84	58108	13.49	433.6
SEm±	0.3	0.5	0.8	0.5	0.03	1454	0.24	10.85
CD (P=0.05)	1.3	NS	NS	NS	0.13	5710	0.95	42.61
Zn & B levels (kg ha <sup>-1</sup> )								
Control	15.7	16.5	91.9	22.9	1.57	46974	11.41	350.6
Zn2.5	16.9	16.9	94.3	22.1	1.70	52928	12.45	395.0
Zn5.0	17.4	17.2	95.1	21.9	1.77	56611	12.91	415.0
B0.5	16.3	16.6	93.1	22.5	1.64	49711	12.02	371.0
B1.0	16.6	16.8	93.7	22.3	1.69	51254	12.35	382.5
Zn2.5B0.5	17.2	17.2	94.7	22.1	1.79	56709	13.18	423.2
SEm±	0.2	0.4	0.5	0.5	0.02	685	0.11	5.11
CD (P=0.05)	0.5	NS	1.4	NS	0.04	1979	0.33	14.77

Table 2: Interactive effect of sulphur, zinc and boron on Production Efficiency (kg ha<sup>-1</sup> day<sup>-1</sup>) of mustard

S levels (kg ha <sup>-1</sup> )	Zn and B levels (kg ha <sup>-1</sup> )					
	Control	Zn2.5	Zn5.0	B0.5	B1.0	Zn2.5B0.5
S0	10.57	11.15	11.02	10.92	11.07	11.54
S20	11.44	12.85	13.26	12.12	12.57	13.50
S40	12.22	13.36	14.45	13.01	13.40	14.49
SEm ±						CD (P=0.05)
Zn and B levels on same level of S						0.20
S at same or different levels of Zn and B						0.30
						1.01

application of 5 kg Zn ha<sup>-1</sup> registered significantly higher CGR as compared to 1 kg B ha<sup>-1</sup>, 0.5 kg B ha<sup>-1</sup> and control (0 kg Zn + 0 kg B ha<sup>-1</sup>), being comparable with 2.5 kg Zn + 0.5 kg B ha<sup>-1</sup> and 2.5 kg Zn ha<sup>-1</sup>. The significant increase in CGR during 31 to 60 DAS might be attributed to adequate availability of Zn, which increased activation and regulation of enzyme related to photosynthesis and auxin synthesis and helps in carbohydrate metabolism and rapid plant growth (Alloway, 2008). Application of varying levels of Zn and boron had no significant influence on CGR at 61 to 90 DAS.

Data revealed that that relative growth rate (RGR) of the mustard crop was not significantly influenced with increasing levels of S at both 31–60 and 61–90 DAS. Critical analysis of data (Table 1) revealed that significant effect of Zn and B application on RGR was observed during 31–60 DAS. The highest RGR was recorded with application of 5.0 kg Zn ha<sup>-1</sup>, which was significantly higher than all the treatments, except 2.5 kg Zn + 0.5 kg B ha<sup>-1</sup> and 2.5 kg Zn ha<sup>-1</sup> alone. However, RGR did not affected remarkably under varying application of Zn and B during 60–90 DAS. The significant increase during 30–60 DAS may be due to adequate availability of Zn increased activation and regulation of enzyme related to photosynthesis and auxin synthesis, which helps in carbohydrate metabolism and rapid plant growth (Alloway, 2008).

Interpretation of data presented in Table 1 revealed that progressive levels of S application up to 40 kg ha<sup>-1</sup> significantly influenced the seed yield of mustard. The application of 40 kg S ha<sup>-1</sup> significantly increased seed yield 21.0% over 0 kg S ha<sup>-1</sup>. It might be due to the enhanced growth and yield attributes with highest level of S application (40 kg S ha<sup>-1</sup>). Moreover, it might be due to adequate availability of sulphur helps in higher chlorophyll formation in leaves, carbohydrate synthesis, higher translocation and assimilation of photosynthates to source resulted higher seed yield (Sipai *et al.*, 2017). Similar results were also reported by Singh *et al.* (2023) and Nayak *et al.* (2022).

Perusal of data indicated that varying levels of Zn and B significantly influenced seed yield of mustard (Table 1). The maximum seed yield was recorded under combined application of 2.5 kg Zn + 0.5 kg B ha<sup>-1</sup>, which were significantly superior than all the treatment being statistically comparable to the application of 5.0 kg Zn ha<sup>-1</sup>. The significant increase in seed yield might be due to balanced and adequate availability of secondary and micronutrients. Better Zn availability promotes numerous enzymes such as carbonic anhydrase and ribulose biphosphate carboxylase, which were involved in carbohydrate metabolism and increased CO<sub>2</sub> fixation (Alloway, 2008). However, B application also helped in better translocation of photosynthates from source to

sink, pollen viability and growth of pollen tube resulted higher dry matter production and seed production (Kumararaja *et al.*, 2015). Similar findings were also observed by Meena *et al.* (2021), Kour *et al.* (2017) and Halim *et al.* (2023).

The significant interaction between different levels of S and varying levels of Zn and B on seed yield is illustrated in Fig.1. Maximum seed yield was recorded with application of 2.5 kg Zn + 0.5 kg B ha<sup>-1</sup>, which was remained at par with application of 5 kg Zn ha<sup>-1</sup> at all levels of S application except 0 kg S ha<sup>-1</sup>. However, under 0 kg S ha<sup>-1</sup>, highest seed yield registered with the application of 2.5 kg Zn + 0.5 kg B ha<sup>-1</sup>, which was statistically at par with 5.0 kg Zn, 2.5 kg Zn and 1.0 kg B ha<sup>-1</sup>, and significantly higher than rest of the treatments. Among different levels of S application, maximum seed yield was recorded with the application of 40 kg S ha<sup>-1</sup> at same or different levels of Zn and B. The Maximum seed yield was recorded with the application of 40 kg S ha<sup>-1</sup> along with 2.5 kg Zn + 0.5 kg B ha<sup>-1</sup> which was remained at par with the application of 40 kg S ha<sup>-1</sup> along with 5 kg Zn ha<sup>-1</sup> and 40 kg S ha<sup>-1</sup> along with 5 kg Zn ha<sup>-1</sup> while significantly higher over rest of the treatments combinations. The significant influence on seed yield might be due to increased availability of secondary and micro nutrients during crop growth and development which helped in better vegetative and reproductive growth. Furthermore, adequate availability of nutrients significantly increased yield attributes which help in achieving the higher seed yield of mustard crop. The results are accordance with the finding of Kour *et al.* (2017) and Meena *et al.* (2022).

Production efficiency (PE) indicates a larger translocation capacity of the source towards the sink. Application of 40 kg S ha<sup>-1</sup> was recorded highest production efficiency which was statistically remained at par with application 20 kg S ha<sup>-1</sup> and both these treatments significantly improved production efficiency by 22.08 and 14.21 per cent as compared to 0 kg S ha<sup>-1</sup>. This might be due to higher assimilation of metabolites in crop plants, relatively higher root biomass, root absorption, better nutrient uptake, increased above ground dry matter accumulation and higher production in unit time (Sheoran *et al.*, 2018). Amongst Zn and B levels, maximum production efficiency was recorded with application of 2.5 kg Zn + 0.5 kg B ha<sup>-1</sup>, which were significantly superior than all the treatment being statistically comparable to the application of 5.0 kg Zn ha<sup>-1</sup>. This significant improvement in production efficiency balanced nutrition which enhanced seed yield and sustainability in mustard production.

Interactive effect of varying levels of S at different level of Zn and B application was found significant and presented in Table 2. Maximum production efficiency

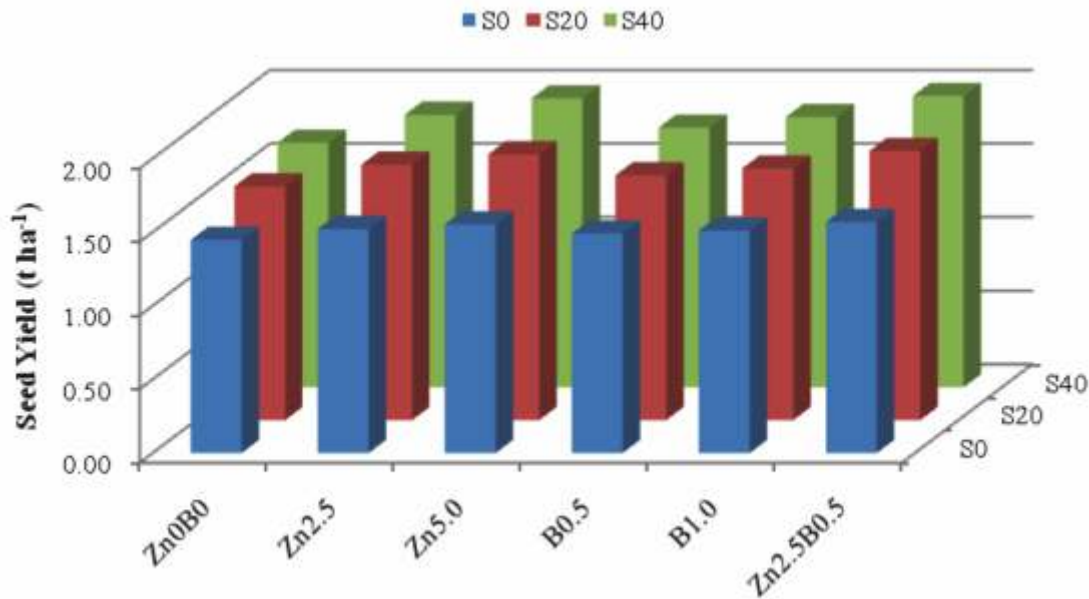


Fig. 1: Interaction effect of S, Zn and B levels on seed yield ( $t\ ha^{-1}$ )

was obtained with the application of 2.5 kg Zn + 0.5 kg B  $ha^{-1}$ , which was remained at par with application of 5.0 kg Zn  $ha^{-1}$  at all levels of S application except 0 kg S  $ha^{-1}$ . However, under 0 kg S  $ha^{-1}$ , production efficiency was found maximum with the application of 2.5 kg Zn + 0.5 kg B  $ha^{-1}$ , which was statistically at par with the application of 5 kg Zn, 2.5 kg Zn and 1.0 kg B  $ha^{-1}$  and significantly higher than rest of the treatments. Among different levels of S application, maximum production efficiency was recorded with application of 40 kg S  $ha^{-1}$  while 0 kg S  $ha^{-1}$  obtained minimum production efficiency at same or different levels of Zn and B. Maximum production efficiency was recorded with the combined application of 40 kg S  $ha^{-1}$  and 2.5 kg Zn + 0.5 kg B  $ha^{-1}$ , which was remained at par with combination of 40 kg S  $ha^{-1}$  along with 5 kg Zn  $ha^{-1}$  and 40 kg S  $ha^{-1}$  along with 5 kg Zn  $ha^{-1}$  while significantly higher over rest of the treatments combinations. The positive influence on production efficiency with application of 40 kg S  $ha^{-1}$  along with 2.5 kg Zn + 0.5 kg B  $ha^{-1}$  seems to be due to balanced and adequate supply of secondary and micronutrients which helped in better reproductive development and ultimately higher seed yield and productivity in per unit time.

It is clearly apparent from data that net returns increased in ascending order with application of S from 0 to 40 kg  $ha^{-1}$ . The increasing in the sulphur levels from 0 to 40 kg S  $ha^{-1}$  enhanced cost of cultivation from 31246 to 33264 Rs.  $ha^{-1}$ . However, maximum net returns (58108 Rs.  $ha^{-1}$ ) were recorded with application of 40 kg S  $ha^{-1}$  which was significantly higher by 8.60%, 29.11% over 20 and 0 kg

S  $ha^{-1}$ . Among the different level of Zn and B, maximum net returns (56709 Rs.  $ha^{-1}$ ) was recorded with application of 2.5 kg Zn + 0.5 kg B  $ha^{-1}$  and enhanced by 20.63% over control. The results are in conformity with the previous findings of Singh *et al.* (2010) and Sha *et al.* (2013). The application of 20 and 40 kg S  $ha^{-1}$  significantly enhanced profitability margins by 63.8 and 98.0 Rs.  $ha^{-1}day^{-1}$ , respectively over application of 0 kg S  $ha^{-1}$ . Amongst Zn and B levels, application of 0.5 kg B, 1.0 kg B, 2.5 kg Zn, 5.0 kg Zn and 0.5 kg B + 2.5 kg Zn  $ha^{-1}$  significantly increased profitability margins by 20.4, 31.9, 44.4, 64.4 and 72.6 Rs.  $ha^{-1}day^{-1}$ , respectively as compared to control (0 kg Zn and B  $ha^{-1}$ ).

### Conclusion

It can be concluded that, application of 40 kg S  $ha^{-1}$  along with 2.5 kg Zn + 0.5 kg B  $ha^{-1}$  performed better in terms of seed yield, net returns, production efficiency and profitability of Indian mustard. Therefore, it could be recommended that 40 kg S  $ha^{-1}$  along with 2.5 kg Zn + 0.5 kg B  $ha^{-1}$  should be applied in Indian mustard for higher seed yield, net returns, production efficiency and profitability particularly under irrigated condition of Bundelkhand regions.

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